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ENHANCED PESTICIDE METABOLISM, A PREVIOUSLY UNREPORTED EFFECT OF DIETARY FIBRE IN MAMMALS*

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Abstract—The effects of various dietary fibres on the metabolism of the organochlorine insecticide, lindane, were compared. Groups of six weanling female Sprague-Dawley rats were fed either a synthetic low-residue diet (LRD), LRD + 10% pectin, LRD + 10% agar, LRD + 10% cellulose, or Purina Lab Chow for 28 days. The animals were then dosed orally with 2.87 mg lindane (containing 1.66 μ Ci [$U-^{14}C$]lindane) and were killed 24 hr later. A smaller proportion of administered radioactivity was recovered in the excreta and selected tissues from the rats fed the LRD diet than from other groups and the fate of the radioactivity not accounted for was investigated in a second experiment using rats fed either LRD unsupplemented, LRD + 10% pectin or the standard chow diet. Pectin and the dietary fibre contained in Purina Lab Chow caused significant alterations in the metabolism of lindane. A significant increase in the excretion of radiolabelled products, a higher level of conjugated chlorophenols and polar metabolites, a significant alteration in the proportions of the excreted chlorophenols and significant stimulation of the enzymes involved in lindane metabolism indicated that dietary fibre such as pectin or the plant fibre in Purina Lab Chow can significantly affect the metabolism of xenobiotics in mammals.

INTRODUCTION

Dietary fibre has been shown to counteract the toxicity resulting from exposure to oestrogens (Ershoff, 1964), glucoascorbic acid (Ershoff, 1954 & 1957), Tween 60 (Ershoff & Hernandez, 1959; Ershoff & Marshall, 1975), chlorazaniol hydrochloride (Ershoff, 1959), the red dye, amaranth (Ershoff & Thurston, 1974), sodium cyclamate (Ershoff, 1972), 2-acetylaminofluorene (Engel & Copeland, 1952), azoxymethane (Ward, Yamamoto & Weisburger, 1973), polychlorinated biphenyls (Kiriya, Inoue, Machinaka & Yoshida, 1973), DDT (Kiriya *et al.*, 1973), heavy metals (Arkhipova & Zorina, 1965) and X-rays (Ershoff, Bajwa, Field & Bavetta, 1969; Ershoff, Bajwa, Shapiro & Bernick, 1967). Little information is available regarding the mechanism by which plant fibres exert their protective effect, but it appears to be unrelated to bulk-forming capacity or cellulose content *per se* (Ershoff, 1974). Moreover, marked differences in the protective properties of various dietary fibres have been reported (Ershoff, 1974; Ershoff & Marshall, 1975). Up to this time, the effect of dietary fibre on the metabolism of xenobiotics has received little attention. This study reports the comparative effects of various dietary fibres on the storage, excretion and metabolism of the organochlorine insecticide γ -hexachlorocyclohexane (lindane; γ -BHC).

EXPERIMENTAL

Thirty weanling female Sprague-Dawley rats were housed in individual metabolism cages and assigned to one of five dietary groups. One group received Pur-

ina Laboratory Chow (Ralston-Purina Co., Inc., St. Louis, MO) throughout the study. The remaining four groups were fed Normal Protein Test Diet, a synthetic low-residue diet obtained from Nutritional Biochemicals, Cleveland, OH. For 28 days prior to treatment with lindane (obtained from the Health Effects Research Laboratory Analytical Reference Standards Repository, Research Triangle Park, NC), the rats were fed Purina Laboratory Chow or the low-residue diet either unsupplemented or supplemented with 10% agar, with 10% Alphacel or with 10% citrus pectin (all three obtained from Nutritional Biochemicals). All animals were then dosed orally with 2.87 mg lindane containing 1.66 μ Ci [$U-^{14}C$]lindane (specific activity 48 mCi/mmol, radiochemical purity 99%; from Amersham/Searle Corp., Arlington Heights, IL) and were killed 24 hr later.

Urine, faeces, fat, liver, kidney and serum samples were taken for analysis of radioactivity. Liver, kidney, fat, serum and faeces samples were subjected to combustion in a Packard Tri-Carb Model 306 sample oxidizer and the radioactivity was determined in a Packard Tri-Carb Model 3380 liquid scintillation spectrometer. The hepatic content of microsomal protein (Lowry, Rosebrough, Farr & Randall, 1951) and of cytochrome P-450 (Omura & Sato, 1964a,b) and the enzyme activity involved in the dehydrogenation and dechlorination of lindane (Chadwick, Chuang & Williams, 1975) were determined. Individual 24-hr urine samples were collected and extracted and the extracts were analysed on a Tracor Model MT-220 gas chromatograph equipped with an electron-capture detector and a Coulson electrolytic conductivity detector as previously described (Chadwick, Simmons, Bryden, Chuang, Key & Chadwick, 1977). Faecal samples were also analysed for moisture content.

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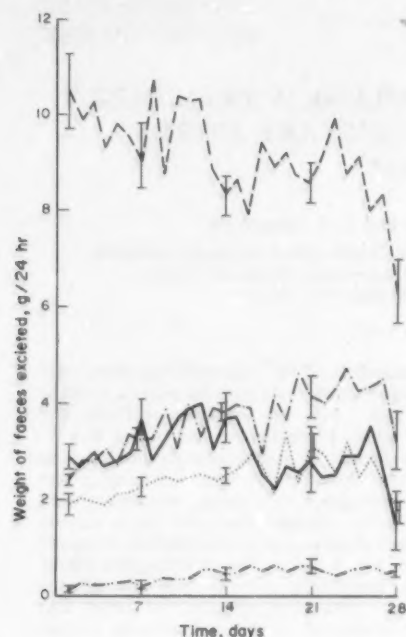


Fig. 1. Effect of dietary fibre on the daily excretion of faeces by rats fed a low-residue diet (LRD: —), LRD + 10% pectin (---), LRD + 10% agar (....), LRD + 10% Alphacel (— — —) or regular lab chow (- · - · -). Values are means for groups of six rats, the SEM being indicated by vertical lines at 1, 7, 14, 21 and 28 days.

To account for radioactivity not recovered from the tissues taken in the first study, another experiment was initiated in which 18 weanling female Sprague-Dawley rats were randomly assigned to one of three dietary groups and fed either the unsupplemented low-residue diet, the low-residue diet containing 10% pectin or Purina Laboratory Chow. Experimental conditions, duration of treatment and analytical procedures were the same as those used in the first experiment, except that after treatment with lindane, the rats were transferred to animal containment chambers (Plas-Labs, Lansing, MI) and the expired air was passed through Carbo-sorb II (Packard, Downers Grove, IL) for $^{14}\text{CO}_2$ collection (Stevens, Hall, Farmer, DiPasquale, Chernoff & Durham, 1977). Urine, faeces, expired air, brain, thymus, lung, heart, liver, kidneys, adrenals, spleen, stomach, small intestine, large intestine, ovaries, bladder, fat, muscle and serum were analysed for radioactivity. Organs were weighed at autopsy.

Body weight, food consumption and urinary and faecal excretion were measured daily throughout the experiments. The energy content of the diet and of faecal samples was determined by combustion in a calorimetric bomb containing oxygen under pressure (ASTM, 1975).

Student's *t* test (Snedecor, 1956) and Duncan's multiple range test (Duncan, 1955) were used as aids in the interpretation of the data from this study. Differences were considered significant at $P < 0.05$ unless otherwise stated.

RESULTS

In the first experiment, the mean daily faecal excretion of all animals receiving fibre was significantly higher throughout the study than that of the rats fed the unsupplemented low-residue diet (Fig. 1). Moreover, the mean daily faecal excretion of the rats fed Purina Laboratory Chow was significantly higher than that of the other rats in the study.

Food consumption and gross energy intake were significantly higher in the rats fed the Purina Lab Chow than in the other rats, yet because of the energy lost in the excreted faeces, these animals had significantly less energy available for weight gain than all the other rats except those fed the low-residue diet supplemented with agar (Table 1). On the other hand, the rats fed the unsupplemented low-residue diet, although showing the lowest values for food consumption and gross energy intake, had high food-conversion efficiencies and high digestion coefficients, and thus had significantly more energy available for weight gain than did rats fed the Purina Lab Chow.

Figure 2 shows that while neither body nor kidney weights differed significantly, the livers of the rats fed Purina Lab Chow were significantly larger than those of the other animals. Moreover, the rats fed Purina Lab Chow had significantly higher enzyme activity *in vitro* for both the dehydrogenation and dechlorination of lindane than all other rats in the study. Hepatic cytochrome *P*-450 content of the rats fed Purina Lab Chow was significantly higher than all other rats except those fed the low-residue diet supplemented with 10% pectin. All animals fed diets containing fibre had significantly higher dechlorinase activity than the rats fed the unsupplemented low-residue diet. There were no significant differences in microsomal-protein content.

Total radioactivity in the urine and faeces of rats fed the Purina Lab Chow was significantly higher than that excreted by the other groups, while that from the rats fed the low-residue diet supplemented with pectin was significantly greater than the radioactivity excreted by animals on the unsupplemented low-residue diet or the low-residue diet containing Alphacel (Table 2). However, urine from the rats fed Purina Lab Chow had a significantly higher concentration of radioactivity than that of the other animals, whereas faeces from the rats receiving the low-residue diet supplemented with pectin contained the highest concentration of faecal radioactivity (Table 2). Moreover the distribution of radioactivity indicated that while there were no significant differences in the urinary excretion of neutral metabolites, the rats fed Purina Lab Chow excreted significantly more chlorophenols and polar metabolites than the other animals (Table 3). In addition, the rats fed the low-residue diet containing pectin excreted significantly more conjugated chlorophenols and polar metabolites in the urine than did the animals on the unsupplemented low-residue diet (Table 3).

Although there was no significant difference in the renal excretion of the neutral metabolites, trace amounts of lindane, 2,3,4,5,6-pentachloro-2-cyclohexen-1-ol and 2,3,4,6-tetrachloro-2-cyclohexen-1-ol were detected by gas chromatography.

Feeding either regular lab chow or the low-residue

Table 1. Effect of dietary fibre on food consumption and energy intake of female rats

Parameter	Values (means $\pm$ SEM) for groups of six rats fed diet no.*					Comparisons†
	(1)	(2)	(3)	(4)	(5)	
Food consumption (g/28 days)	345 $\pm$ 12.6	400 $\pm$ 20.3	387 $\pm$ 15.4	410 $\pm$ 11.6	514 $\pm$ 10.4	5 > all; 4, 2, 3 > 1
Food conversion efficiency‡	0.30 $\pm$ 0.01	0.28 $\pm$ 0.01	0.29 $\pm$ 0.01	0.28 $\pm$ 0.01	0.23 $\pm$ 0.01	All > 5
Energy intake (kcal/rat/28 days):						
gross	1548 $\pm$ 56.73	1755 $\pm$ 88.92	1730 $\pm$ 68.78	1774 $\pm$ 50.12	2050 $\pm$ 41.70	5 > all; 4, 2 > 1
digestible§	1512 $\pm$ 54.68	1567 $\pm$ 84.02	1494 $\pm$ 56.86	1550 $\pm$ 45.36	1439 $\pm$ 43.18	NS
Digestion coefficient	97.7 $\pm$ 0.18	89.2 $\pm$ 1.30	86.3 $\pm$ 0.32	87.3 $\pm$ 0.28	70.2 $\pm$ 1.05	1 > all; 2, 4, 3 > 5; 2 > 3
Energy available for gain (kcal/rat/day)**	25.8 $\pm$ 1.36	27.2 $\pm$ 2.17	24.2 $\pm$ 1.14	25.4 $\pm$ 1.10	20.3 $\pm$ 1.20	2, 1, 4 > 5

NS = Not significant

*(1) Low-residue diet (LRD); (2) LRD $\pm$ 10% pectin; (3) LRD $\pm$ 10% agar; (4) LRD $\pm$ 10% Alphacel; (5) Purina Lab Chow.†Comparisons reported differ significantly ($P < 0.05$) by Duncan's multiple range test.

‡Food conversion efficiency = weight gained (g)/diet consumed (g).

§Digestible energy intake = gross energy intake - energy excreted in faeces.

||Digestion coefficient = digestible energy intake $\times$ 100/gross energy intake.**Energy available for gain = digestible energy intake in 24 hr - (body weight (kg)^{0.75} $\times$ 115 kcal).

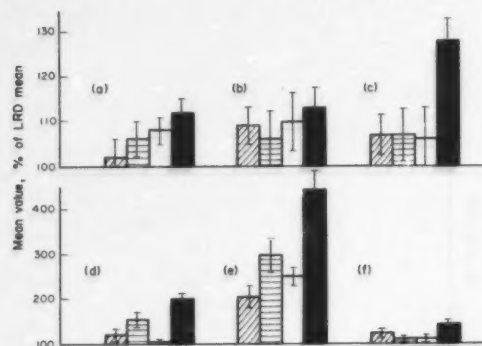


Fig. 2. Effect of dietary fibre on (a) body weight, (b) kidney weight, (c) liver weight, (d) the dehydrogenation of lindane, (e) the dechlorination of lindane and (f) the hepatic cytochrome P-450 content. The mean value for the six rats on the low-residue diet (LRD) is represented as 100%, the mean values of the other dietary groups being presented as a percentage of the LRD value (dietary mean $\times$ 100/LRD mean). Vertical lines indicate the SEM and in each block the bars indicate the values for the groups of six rats fed LRD + 10% pectin (▨), LRD + 10% agar (▤), LRD + 10% Alphacel (□) and regular lab chow (■).

diet plus 10% pectin significantly altered the relative proportions of the urinary tetrachlorophenol metabolites (Fig. 3). While rats on either of these diets excreted a significantly higher proportion of 2,3,4,6-tetrachlorophenol than the other animals, the rats fed Purina Lab Chow excreted significantly more of this compound than those fed the low-residue diet containing pectin. On the other hand, all four groups on the low-residue diet excreted a significantly higher proportion of 2,3,4,5-tetrachlorophenol than did those fed Purina Lab Chow. Moreover the rats fed the low-residue diet plus pectin excreted a significantly smaller proportion of 2,3,4,5-tetrachlorophenol than did those fed the low-residue diet or the low-residue diet plus Alphacel.

Since rats fed the low-residue diet excreted significantly less radioactivity than those fed Purina Lab Chow or the low-residue diet supplemented with pectin, it was assumed that the animals consuming the low-residue diet were storing the radiolabelled lindane. However, no significant differences between the groups were found in serum, liver, kidney or fat levels of radioactivity. To account for the radioactivity not recovered from the excreta or tissues of the rats on the unsupplemented low-residue diet, a second experiment was initiated using the unsupplemented low-residue diet, the low-residue diet supplemented with 10% pectin and Purina Lab Chow. This time urine, faeces, expired air, brain, thymus, lung, heart, liver, kidneys, adrenals, spleen, stomach, small intestine, large intestine, ovaries, bladder, fat, muscle and serum were analysed for radioactivity.

Again, feeding either regular lab chow or the low-residue diet containing pectin resulted in a significant increase in the total excretion of radioactivity over that of the animals on the unsupplemented low-residue diet (Table 4). In this second experiment, a marked decrease in the 24-hr faecal collection was noted for all dietary groups. This may have been due to stress resulting from the transfer of the animals to a different type of cage 24 hr before they were

killed. Thus, although the radioactivity in the faeces of the rats fed Purina Lab Chow was again significantly greater than that of the rats fed the low-residue diet, the radioactivity in the faeces of the rats fed the low-residue diet containing pectin was not. Small amounts of radioactivity were expired by all dietary groups (Table 4), the amount expired both by the rats fed Purina Lab Chow and by those fed the low-residue diet supplemented with pectin being significantly greater than that recovered from the animals fed the unsupplemented low-residue diet.

Only the tissues listed in Table 4 contained significantly differing levels of radioactivity in the three groups. In all cases, the rats on the low-residue diet had the lowest level of radiolabelled material. It was noted, however, that the organ weights of the animals on the low-residue diet were lower and therefore a comparison of total organ weight as a percentage of body weight was made (Table 5). Organs of the rats fed the unsupplemented low-residue diet comprised 13.6% of the total body weight, a proportion significantly lower than the 17 and 19% found in the rats fed the low-residue diet containing pectin or Purina Lab Chow, respectively.

DISCUSSION

Dietary fibre is not just an inert substance that passes unchanged through the gut. It consists of a heterogeneous group of compounds, including cellulose, polysaccharides, pectic substances, hemicelluloses and lignins, with distinct physical, chemical and metabolic properties (Cummings, 1973; Trowell, 1972). The amounts of these components vary according to the type of plant and its anatomy. While the water-adsorption capacity of cellulose is moderate, that of the other polysaccharides is strong. Lignin, a hydroxylated aromatic polymer, absorbs acid compounds but not significant amounts of water. Pectic substances form gels with water and cause dilution of faecal constituents (Williams & Olmsted, 1936).

In accordance with these findings, the diets used in this study, a low-residue diet, unsupplemented or supplemented with 10% pectin, 10% agar or 10% Alphacel, and Purina Lab Chow, resulted in faeces with moisture contents of 23.5, 48.0, 38.1, 19.0 and 39.2% respectively. Moreover, natural plant fibre was shown to bind significantly more bile salts than non-nutritive fibre such as cellophane, spangles and cellulose (Kritchevsky & Story, 1974). Further evidence that dietary fibre is not inert comes from reports that dietary-fibre constituents from molasses (Fahey, Williams & McLaren, 1976) and from corn, alfalfa and spinach (McLaren, Cuppett, Williams, Fahey & Smith, 1974) are growth stimulants. Evidence for the involvement of dietary fibre in metabolism includes reports that it stimulates the activity of hepatic cholesterol 7 α -hydroxylase, a cytochrome P-450 enzyme (Johansson, 1970; Morgan, Heald, Atkin & Green, 1974). However, fibre-induced acceleration of toxicant metabolism, such as that observed in this study, has not been previously reported and may constitute a mechanism whereby dietary fibre exerts a protective effect against the toxicity of some xenobiotics.

A significantly greater excretion of radiolabelled lindane metabolites (Tables 2 & 4), a significant increase in the metabolism of lindane to polar metabolites

Table 2. Effect of diet on excretion of radioactivity after treatment of female rats with [^{14}C]lindane

Radioactivity excreted	Values (means $\pm$ SEM) for groups of six rats fed diet no.*					Comparisons†
	(1)	(2)	(3)	(4)	(5)	
Total (dpm $\times 10^{-5}$)	3.09 $\pm$ 0.20	4.85 $\pm$ 0.83	3.57 $\pm$ 0.12	3.38 $\pm$ 0.24	6.25 $\pm$ 0.25	5 > all
(% of dose)	8.44 $\pm$ 0.54	13.20 $\pm$ 2.25	9.76 $\pm$ 0.32	9.24 $\pm$ 0.65	17.10 $\pm$ 0.69	2 > 4, 1
In urine (dpm $\times 10^{-5}$)	2.87 $\pm$ 0.14	3.55 $\pm$ 0.36	3.19 $\pm$ 0.14	3.09 $\pm$ 0.24	4.74 $\pm$ 0.16	5 > all
(% of dose)	7.85 $\pm$ 0.39	9.70 $\pm$ 0.99	8.72 $\pm$ 0.39	8.45 $\pm$ 0.66	13.00 $\pm$ 0.42	5 > all
(dpm $\times 10^{-5}$ /ml)	0.057 $\pm$ 0.003	0.071 $\pm$ 0.007	0.064 $\pm$ 0.003	0.062 $\pm$ 0.005	0.095 $\pm$ 0.003	5 > all
In faeces (dpm $\times 10^{-5}$)	0.26 $\pm$ 0.10	1.30 $\pm$ 0.51	0.38 $\pm$ 0.17	0.29 $\pm$ 0.08	1.51 $\pm$ 0.18	2 > 1
(% of dose)	0.72 $\pm$ 0.26	3.55 $\pm$ 1.40	1.04 $\pm$ 0.19	0.80 $\pm$ 0.23	4.12 $\pm$ 0.50	5, 2 > 3, 4, 1
(dpm $\times 10^{-5}$ /g)	0.71 $\pm$ 0.16	1.87 $\pm$ 0.82	0.20 $\pm$ 0.04	0.18 $\pm$ 0.04	0.40 $\pm$ 0.03	2 > 5, 4, 3

* (1) Low-residue diet (LRD); (2) LRD + 10% pectin; (3) LRD + 10% agar; (4) LRD + 10% Alphacel; (5) Purina Lab Chow.

† Comparisons reported differ significantly ($P < 0.05$) by Duncan's multiple range test.

Table 3. Effect of diet on the distribution of radioactivity in the urine of female rats treated with [^{14}C]lindane

Identity of metabolites	Urinary radioactivity (dpm $\times 10^{-5}$) as means $\pm$ SEM for groups of six rats on diet no.*					Comparisons†
	(1)	(2)	(3)	(4)	(5)	
Neutral metabolites‡	0.094 $\pm$ 0.035	0.078 $\pm$ 0.006	0.086 $\pm$ 0.020	0.052 $\pm$ 0.004	0.098 $\pm$ 0.012	NS
Free chlorophenols§	0.74 $\pm$ 0.04	0.80 $\pm$ 0.04	0.80 $\pm$ 0.05	0.81 $\pm$ 0.05	1.32 $\pm$ 0.10	5 > all
Conjugated chlorophenols	0.92 $\pm$ 0.04	1.25 $\pm$ 0.12	1.10 $\pm$ 0.07	1.07 $\pm$ 0.06	1.76 $\pm$ 0.10	5 > all
Polar metabolites**	0.97 $\pm$ 0.04	1.26 $\pm$ 0.11	1.09 $\pm$ 0.03	1.08 $\pm$ 0.05	1.64 $\pm$ 0.07	2 > 1
						5 > all
						2 > 1

* (1) Low-residue diet (LRD); (2) LRD + 10% pectin; (3) LRD + 10% agar; (4) LRD + 10% Alphacel; (5) Purina Lab Chow.

† Comparisons reported differ significantly ($P < 0.05$) by Duncan's multiple range test.

‡ Extracted with benzene from acid urine (pH = 2) but did not partition into 0.15 N-NaOH.

§ Extracted with benzene from acid urine (pH = 2) and partitioned into 0.15 N-NaOH.

|| Extracted with benzene from hydrolysed urine.

** Remained in residual hydrolysed urine after extraction.

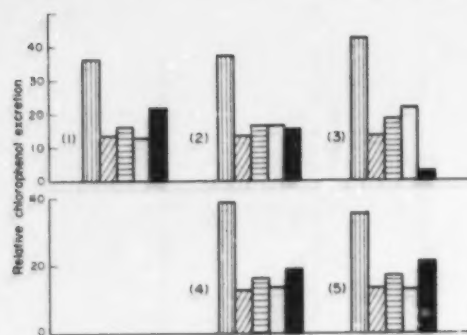


Fig. 3. Effect of dietary fibre on the excretion patterns of the chlorophenol metabolites of lindane in groups of six rats fed (1) low-residue diet (LRD), (2) LRD + 10% pectin, (3) regular lab chow, (4) LRD + 10% agar or (5) LRD + 10% Alphacel. Each bar is the mean for six animals and shows, for each dietary group, the percentage of the total chlorophenol excretion represented by (□) 2,4,6-, (▨) 2,3,5- and (▩) 2,4,5-trichlorophenol and (■) 2,3,4,5-tetrachlorophenol.

and conjugated chlorophenols (Table 3), a significant alteration in the relative proportions of the excreted chlorophenol metabolites of lindane (Fig. 3) and significant stimulation of the enzymes involved in lindane metabolism (Fig. 2) support the contention that a dietary fibre such as pectin or the variety of plant fibres in Purina Lab Chow can affect the metabolism of lindane. Total dry weight of the faeces excreted by rats fed Purina Lab Chow equalled 31.5% of the quantity of food consumed by these animals during the experiment and this proportion was significantly higher than that of the other rats in the study. This indicates that the dietary fibre content of Purina Lab Chow is significantly greater than that of the other diets. Although the significantly high level of dietary fibre in Purina Lab Chow is apparently related to the significantly increased lindane metabolism in animals fed this diet, other factors, such as the type of dietary protein, lipid or trace contaminants could have contributed to the increased metabolism. Such factors, however, are not involved in the increased lindane metabolism noted in rats fed the low-residue diet supplemented with pectin.

Table 4. Effect of diet on radioactivity excreted and retained in the tissues after treatment of female rats with [^{14} C]lindane

Radioactivity excreted or retained	Values for rats fed diet no.†		
	(1)	(2)	(3)
Total (dpm $\times 10^{-5}$)	2.78 $\pm$ 0.28	3.88 $\pm$ 0.38**	5.10 $\pm$ 0.45**
(% of dose)	7.40 $\pm$ 0.85	10.20 $\pm$ 1.01	13.60 $\pm$ 1.35
In urine (dpm $\times 10^{-5}$)	2.72 $\pm$ 0.28	3.73 $\pm$ 0.39*	4.36 $\pm$ 0.45**
(% of dose)	7.24 $\pm$ 0.84	9.85 $\pm$ 1.05	11.60 $\pm$ 1.31
faeces‡ (dpm $\times 10^{-5}$)	0.006 $\pm$ 0.004	0.097 $\pm$ 0.061	0.580 $\pm$ 0.150**
(% of dose)	0.013 $\pm$ 0.010	0.247 $\pm$ 0.148	1.560 $\pm$ 0.410
breath (dpm $\times 10^{-5}$)	0.057 $\pm$ 0.006	0.069 $\pm$ 0.002*	0.156 $\pm$ 0.038**
(% of dose)	0.150 $\pm$ 0.017	0.181 $\pm$ 0.006	0.423 $\pm$ 0.106
brains§	0.40 $\pm$ 0.07	0.56 $\pm$ 0.06	0.70 $\pm$ 0.05**
livers§	3.86 $\pm$ 1.34	6.82 $\pm$ 0.98*	7.96 $\pm$ 0.89**
kidneys§	0.83 $\pm$ 0.18	1.20 $\pm$ 0.21	1.58 $\pm$ 0.15**
stomachs§	1.03 $\pm$ 0.25	2.36 $\pm$ 0.77	4.57 $\pm$ 1.16**
large intestines§	7.62 $\pm$ 1.05	12.90 $\pm$ 2.65*	8.88 $\pm$ 0.98
muscle	0.22 $\pm$ 0.04	0.39 $\pm$ 0.06**	0.50 $\pm$ 0.07**

†(1) Low-residue diet (LRD); (2) LRD + 10% pectin; (3) Purina Lab Chow.

‡Two rats on diet (1) and one on diet (2) did not excrete faeces within the 24-hr period.

§Expressed as dpm $\times 10^{-4}$ /whole organ, or pair of kidneys.

||Expressed as dpm $\times 10^{-4}$ /g tissue.

Values are means $\pm$ SEM for groups of six rats and those marked with asterisks differ significantly from the LRD values: * $P < 0.10$; ** $P < 0.05$.

Table 5. Effect of dietary fibre on body weight and the combined weight of the excised organs of female rats

Parameter	Values for rats fed diet no.†		
	(1)	(2)	(3)
Body weight (g)	202 $\pm$ 8.91	201 $\pm$ 2.55	219 $\pm$ 7.71
Total organ weight‡ (g)	27.5 $\pm$ 1.59	34.1 $\pm$ 0.71*	42.0 $\pm$ 2.23*
Organ weight/body weight ratio	0.136 $\pm$ 0.003	0.170 $\pm$ 0.004*	0.192 $\pm$ 0.007*

†(1) Low-residue diet (LRD); (2) LRD + 10% pectin; (3) Purina Lab Chow.

‡Organs excised and weighed comprised liver, kidneys, stomach, small intestine, large intestine, brain, thymus gland, heart, lungs, spleen, adrenal glands, bladder and ovaries.

Values are means $\pm$ SEM for groups of six animals and those marked with an asterisk differ significantly (Student's t test) from the LRD values: * $P < 0.05$.

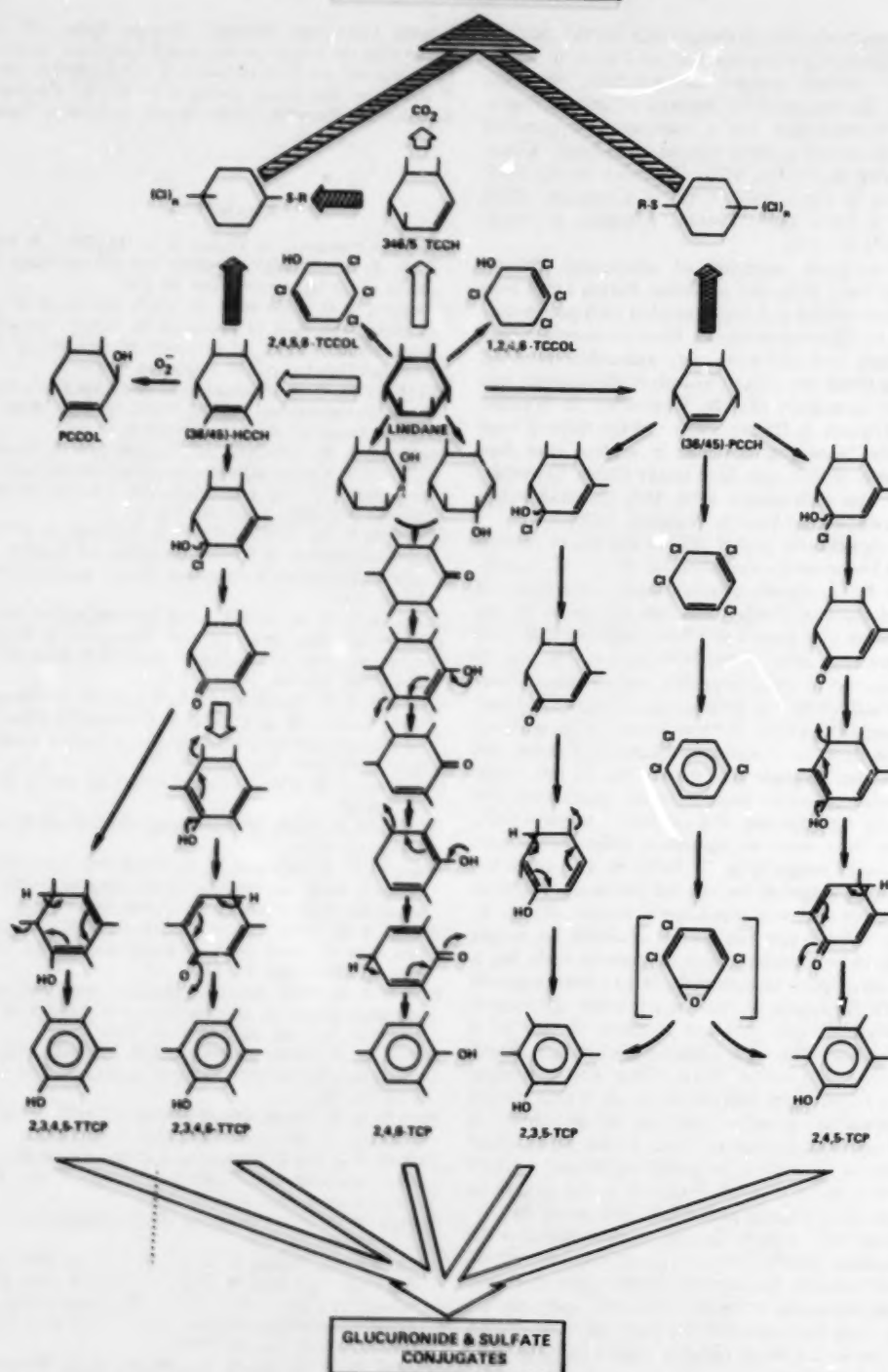


Fig. 4. Effect of dietary fibre on the metabolism of lindane. The open arrows indicate the metabolic pathways affected by dietary fibre in this study. The shaded arrows indicate pathways that may be influenced in view of the elevated excretion of radiolabelled polar lindane metabolites by rats fed Purina Lab Chow or low-residue diet + 10% pectin. Where the configurations of the compounds are known, this is indicated by fractional notation, numbers in the numerator denoting chlorine above and numbers in the denominator denoting chlorine below the plane of the ring. Abbreviations: TCCOL, tetrachlorocyclohexene; PCCOL, pentachlorocyclohexene; HCCH, hexachlorocyclohexene; PCCH, pentachlorocyclohexene; TTCP, tetrachlorophenol; TCP, trichlorophenol.

The observed effects of dietary fibre on the metabolism of lindane are summarized in Fig. 4, in which the open arrows indicate the metabolic pathways affected. The proposed mechanisms of lindane degradation in mammals are a composite of previous observations and current reports (Chadwick, Chadwick, Freal & Bryden, 1977; Chadwick *et al.*, 1975; Chadwick & Freal, 1972; Freal & Chadwick, 1973; Grover & Sims, 1965; Tanaka, Kurihara & Nakajima, 1976 & 1977).

The increased excretion of conjugated chlorophenols (Table 3) by rats fed either Purina Lab Chow or the low-residue diet supplemented with pectin may reflect the influence of dietary fibre on intestinal bacteria. Both rats and man carry anaerobic intestinal bacteria which are able to hydrolyse glucuronide and sulphate conjugates (Reddy, Weisburger & Wynder, 1974; Renwick & Draser, 1976) and the ratio of total anaerobes to aerobes is higher in western man than in societies with a high fibre intake (Aries, Crowther, Drasar, Hill & Williams, 1969; Hill, Crowther, Drasar, Hawksworth, Aries & Williams, 1971).

The significantly higher dechlorination of lindane to 3,4,5,6-tetrachlorocyclohexene (Fig. 2) accompanied by a significantly increased expiration of labelled material (Table 4) in rats fed pectin or the plant fibres in Purina Lab Chow indicates that dietary fibre may affect a metabolic pathway similar to one reported in micro-organisms (Matsumura, Berezet & Patil, 1976). The latter group demonstrated that micro-organisms such as *Pseudomonas putida* dechlorinate lindane to 3,4,5,6-tetrachlorocyclohexene and then further degrade this metabolite, by an FAD-dependent reductive dechlorination mechanism followed by ring opening and oxidation, to yield CO₂.

Since there were no significant differences in terminal body weight (Fig. 2; Table 6) and since the total organ weight of the rats fed the unsupplemented low-residue diet was significantly smaller (Table 6), it is postulated that the energy available for weight gain in these animals (Table 1) goes to body fat, a high-energy pool in mammals. It has been reported that the fat depots of rats on a purified corn-starch diet weighed twice as much as those of rats fed a whole-grain corn diet (Winnie, Schemmel, Rand, Mickelsen & Leveille, 1973). Thus although there were no significant differences in the concentration of radioactivity stored in the body fat of animals in this study, extensive storage in larger fat depots could account for the radioactivity that was neither excreted (Tables 2, 4) nor stored (Table 5) in the organs of the rats fed the unsupplemented low-residue diet.

In summary, dietary fibre can significantly alter the metabolism of lindane and presumably other environmental toxicants. Because of different physical, chemical and metabolic properties, however, some dietary fibres, such as pectin and the plant fibres in Purina Lab Chow, are more effective than others, such as agar and cellulose.

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